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THE EFFECT OF ARTIFICIAL SELECTION ON BRISTLE NUMBER IN DROSOPHILA AMPELOPHILA AND ITS INTERPRETATION

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About two years ago I began an experiment to test the effect of artificial selection in a bisexual form. Drosophila ampelophila was chosen after a careful search through the list of material which could be bred in the laboratory. There were two principal reasons for using this material. First, it is easily bred, and second, because of the four sets of linked genes described by Morgan and others, it is possible to better interpret how the results of selection have been accomplished. I wish to emphasize that the interpretation of the results is the important part of the problem. Practically every one admits that selection may be, in certain cases, effective.

The present work is not a repetition of McDowell's, although the character, bristle number, has been used. He used the bristles on the thorax, while I have used the bristles on the scutellum. Some of our final conclusions may agree, yet, the work is very different and I believe my own conclusions have been carried to a more definite termination. McDowell did not attempt to link up the factors which he believed the cause of extra bristle number with any other genes.

The experiment was started by mating a female with one extra bristle on the scutellum to a normal male (four bristles is the normal number). Both flies were taken from a mass culture which had been kept in the laboratory for about three months. Counts in this mass culture before the experiment began gave 612 normal flies and the one female with one extra bristle. The result of this cross (female five by normal male) was 226 normal flies and two females with one extra bristle. These two F_1 females with one extra bristle were mated to F_1 normal brothers. These two pairs gave F_2 offspring as follows: 935 normal, 39 with one extra bristle, and four with two extra bristles, a ratio of extras to normals of 1: 21.7. From these F_2 offspring, the flies with

extra bristles were mated. This method of selecting the high grade parent has been continued for 38 generations. A rise in the per cent of extra bristled flies and also in the mean bristle number has been produced until in the last generations of selection no normal flies were found and the mean number of bristles in the twenty-ninth generation was 9.084. From the twenty-ninth to the thirty-eighth generation the mean remained practically the same. The highest bristle number found in any one individual fly was 15.

I cannot give details, but I think these figures are sufficient to show that selection has been effective. How then has it been effective? Have the results been produced by selecting merely somatic variations? Have they been produced by selecting the variations of a single gene, or have they been produced by getting rid of or by piling factors? The possibility that selection can act upon somatic variations, I believe, can now be dismissed without much consideration. Practically every one admits that variations must be germinal in order to be inherited. As to the second and third possibilities, my evidence is in favor of the third.

In the selection line the bristle number in the females is slightly higher than in the males. This indicated that there might be a sex-linked factor present, which when homozygous produced a different effect than when heterozygous. An experiment was devised to eliminate the X-chromosome but retain the others. This was done as follows: A male from the high selection line was mated to a bar female (bar is a sex-linked dominant). The F_1 males will get their X-chromosome from the bar female and hence will be bar. Of the other three pairs of chromosomes, one of each pair will come from the high selection line and the other from the bar line. Some of these F_1 males have extra bristles. These were mated to bar females from stock. All flies from this cross will get their X-chromosomes from the bar line. Some of them may get one member of each of the second, third, and fourth pairs from the high selection line. Since extra bristle number is partially dominant to the normal, such flies might have extra bristles if there are any genes for extra bristles in the second, third, or fourth chromosomes. Some of the flies from this cross did have extra bristles. They were mated and the line has been inbred to see whether the bristle number could be increased until it reached the mean in the high selection line. If so, then the X-chromosome could carry no gene for extra bristles. If the mean could not be raised, then it would indicate that the X-chromosome carried such a gene. Five generations of inbreeding has failed to raise the mean above 5.2.

Further, by crossing the high selection line to eosin, miniature and to eosin ruby forked (sex-linked characters), and mating the F_1 females back to the recessives, it comes out clearly that a gene influencing bristle number is located in the X-chromosome, somewhere near eosin. Of the cross-overs between eosin and miniature and between eosin ruby and forked, miniature and forked flies have a higher bristle number than the eosin, and eosin ruby.

The high selection line was also mated to black, pink, bent stock. The gene for black is in the second, that for pink in the third, and that for bent in the fourth chromosome. The F_1 flies were mated inter se and the F_1 males were mated back to black, pink, bent females. The normal, the black, and the bent flies from these crosses had a much higher bristle number than the pink flies. This fact indicated that there probably was a factor for bristle number in the third chromosome. To test this possibility the high selection line was mated to sepia spineless kidney sooty rough stock. The genes for these characters are located in the third chromosome. The F_1 females were mated to sepia spineless kidney sooty rough males. If crossing-over had occurred, this cross should have enabled me to link up the gene for extra bristles (if one is present) with one of the other genes. Unfortunately, only a low percentage of crossing-over occurs and hence the cross yielded no results.

Another method of analysis was used. A female from the high selection line was crossed to a sepia spineless kidney sooty rough male. The F_1 male from this cross was mated to a sepia spineless kidney sooty rough female. The offspring are normal females and males, and sepia spineless kidney sooty rough females and males. Some of the normal females and males and some of the sepia spineless kidney sooty rough females had extra bristles. None of the sepia spineless kidney sooty rough males had extra bristles. When the chromosomes of these flies are analyzed, it is found that the normal females may get one member of each of the second, third, and fourth chromosome pairs from the selection line and must get one of the X-chromosomes from this line. The normal males may get one chromosome of each of the second, third, and fourth chromosome pairs from the selection line, but they get their X-chromosome from the sepia, spineless, kidney, sooty, rough line. The sepia spineless kidney sooty rough females get both their third chromosomes from the sepia, spineless, kidney sooty rough line and may get one member of each of the second and fourth pairs from the selection line. They get one X-chromosome from the selection line and one from the other. The sepia spineless kidney sooty rough males, however, get their X-chromosome and both third chromosomes from the sepia spineless kidney sooty rough line and may get one chromosome of the second and fourth pairs from the selection line. Since these sepia spineless kidney sooty rough males have no extra bristles, it would seem that the X- and the third chromosomes carry the factors for extra bristle number.

A back selection line started from the eleventh generation and carried for twenty-five generations, changed slightly in the first few generations of selection and then remained practically unchanged. A mass culture started a year ago has not returned to the normal.

My conclusion then is that there are, at least, two factors for extra bristle number and that one of these is located in the first and one in the third chro-

mosome. I am inclined to think there are more than two. It seems probable that one of these factors was present at the beginning of selection and that the others occurred as mutations during the course of the experiment.

The complete data and analysis will be given in the final paper.

THE REACTIONS OF THE MELANOPHORES OF AMIURUS TO LIGHT AND TO ADRENALIN

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Communicated by G. H. Parker, January 8, 1918

The following is a brief summary of results obtained in experiments to test the reactions of the melanophores in the skin of Amiurus to light and to adrenalin. The fishes tested were kept under as normal conditions as possible and no fish was used until it had become accustomed to its laboratory surroundings and to handling.

The melanophores of Amiurus contract under the influence of light of ordinary intensity and expand in the dark. Fish kept in white porcelain aquaria contract the melanophores to a much greater extent than do animals kept in black lined aquaria under similar conditions of overhead illumination. When the eyes are removed from normal healthy animals the latter remain dark under all light conditions. There are considerable differences in individuals with respect to the power of contraction of the melanophores. Some fishes become extremely light owing to complete contraction of the pigment cells; others, under similar conditions, never become so light. This cannot be explained entirely by the relative numbers of melanophores per unit area of body surface, as was shown by several counts. It may be due, possibly, to differences in nervous excitability.

If some 'sensitive' individuals are raised to a high pitch of nervous irritability, the melanophores are contracted to the maximum extent, and remain in this condition for a protracted period, even when the fishes are placed in the dark. One such fish was kept in the dark for three weeks and no expansion was observed in the melanophores. These cells appeared to be in a condition comparable to tetanus.

When such an 'excited' animal, with melanophores contracted, is etherized, the pigment cells expand and the fish becomes dark. On coming out of the ether, the melanophores contract slightly, but if the fish is now placed in the dark, the pigment cells gradually assume the expanded condition. If, however, the eyes are removed whilst the fish is under ether, there is no return to the contracted condition when the animal is subsequently kept in the light. The fact that there was no return to the contracted condition

of the melanophores after the eyes were removed, both in normal and 'excited' animals, suggests that there is an adaptive significance to be attached to the reactions of the melanophores, and that these reactions are mediated by the nervous system through the eyes.

Excised portions of the skin of Amiurus with melanophores expanded, were immersed in solutions of adrenalin of various strengths, others in tap water and still others in physiological salt solution, and the rates of contraction of the melanophores observed under the microscope.

Strength of adrenalin solution	Average time for maximum contraction
1 : 5000	Almost immediately
1 : 10,000	4 to 6 minutes
1 : 100,000	6 to 8 minutes
1 : 1,000,000	16 to 40 minutes
1 : 2,000,000	120 minutes
1 : 5,000,000	Partial contraction in 3 hours

If an excised portion of the skin with melanophores contracted is placed in ether water, the melanophores expand slowly, whilst the controls, in physiological salt solution or in tap water, show no change.

Intra-muscular injections of adrenalin were made, and others of physiological salt solution as controls. The results on the melanophores were in every way comparable to those found for the excised portions of the skin; that is, the melanophores contracted after injection of adrenalin at rates varying with the strength of the injection. The minimum dilution found effective was 1: 5,000,000. An injection of 1: 10,000,000 caused local contraction of the melanophores in the area around the point where the injection was made, but not in other parts of the skin.

The effect of adrenalin disappears after a time varying with the strength of the injection and ranging from one to several hours.

If a fish, which has been injected with 1: 1,000,000 part of adrenalin, is etherized when it has reached a condition of maximum contraction of the melanophores, there is a perceptible darkening, due to partial expansion of the melanophores. On coming out of the ether the fish returns to the light condition, that is, its melanophores contract. If the fish is subsequently kept in the dark the melanophores gradually expand.

Some fish were removed for a time from the water and two pieces of filter paper, one moistened with physiological salt solution and one with a 1: 100,000 solution of adrenalin were placed on the skin. After fifteen minutes, both were removed. The area of the skin covered by the filter paper moistened with salt solution had become lighter, but darkened rapidly on removal of the paper. The portion covered by the paper moistened with adrenalin solution was quite light, and remained so for about three hours. The influence of the adrenalin spread only slightly to adjacent parts, but a light band appeared in some cases where a little of the solution had run down from the paper.

From the above results it is seen that the melanophores in the skin of Amiurus react to direct stimulation by adrenalin. They are also subject to nervous control, and this control is mediated through the eye. There is also a suggestion of the secretion of a hormone under certain conditions and of its influence on the melanophores.

* Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoölogy at Harvard College, No. 306.

FURTHER EXPERIMENTS ON THE SEX OF PARTHENOGENETIC FROGS

By Jacques Loeb

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Communicated January 23, 1918

It seemed necessary to furnish proof that by the methods of artificial parthenogenesis not only normal larvae can be produced from unfertilized eggs but that these larvae can also develop into full sized normal adults. This task is difficult to accomplish in sea urchins and thus far only Delage has reported that he has succeeded in raising one parthenogenetic larva of a sea urchin to the sexually mature form.

The possibility of producing artificial parthenogenesis in the eggs of the frog by the method of puncture, as demonstrated in the experiments of Guyer and of Bataillon, seemed more promising. The writer has made use of this method for deciding the question whether such frogs can reach the adult size, and determining their sex. He has now raised twenty leopard frogs to an age of from ten to eighteen months, and nine of these frogs are still alive. Some of these male frogs have reached the full size of the adult male leopard frog. *We are, therefore, entitled to say that the frogs produced by artificial parthenogenesis can develop into adults of full size and of an entirely normal character.*

Loeb and Bancroft[1] tried to ascertain the sex of a parthenogenetic frog immediately after metamorphosis but found the gonads in the intermediate stage, i.e., testes containing a few eggs, though it was obvious that the frog was developing into a male. It was clear that older frogs were needed for the decision of the problem of sex. The writer has been able to ascertain the sex in nine frogs of the age of from ten to eighteen months, and in all of these the ambiguity inherent in the younger frogs had disappeared. He has already reported that the first two of these parthenogenetic frogs has normal mature testes containing fully developed spermatozoa.[2] No eggs were found in these testes.

The next four frogs examined were also males, so that the problem seemed settled when a year ago last summer one parthenogenetic frog, sixteen months

old, was found whose gonads were macroscopically and microscopically well developed ovaries. The next frog was again a male. Although the possibility of an error in method seemed excluded the writer did not wish to publish the fact that both sexes appear in parthenogenetic frogs without having checked the result by a new series of experiments.

These experiments were started in February, 1917. The same precautions as in the older experiments were used. Copulating females which had not yet laid any eggs were separated from their males and kept separated for at least twenty-four hours. The females were repeatedly washed with water during the time of isolation, and directly before the experiment were submerged in 90% alcohol and left there to die. They were taken out, their abdominal cavity was opened with sterilized instruments and the oviduct laid bare. The eggs were taken out from the oviduct with sterilized instruments, and precautions were taken that the eggs did not come in contact with the hands of the experimenter or with the skin or outside of the frog. Alternate lots of about 50 to 100 eggs were punctured or kept untreated as controls. None of these non-treated eggs ever developed. From the punctured, unfertilized eggs ten developed into frogs, of which nine are still alive. The tenth was killed December 21 and the microscopic examination of its gonads showed that it was a female. This leaves then no doubt that both sexes can be produced from the unfertilized eggs of the frog. We have thus far obtained seven male frogs and two females, while the determination in two was missed by accident.

How can we account for the production of both sexes? The diploid number of chromosomes in the frog seems to be 26, according to Swingle,[3] and, therefore, the haploid number 13. The question then arises: Do we find the diploid or haploid number of chromosomes in the cells of the parthenogenetic frog? Brachet[4] found the diploid number in the somatic cells of a parthenogenetic tadpole eighteen days old, but, of course, it was out of the question to ascertain the sex of the tadpole.

The gap can be filled by counting the chromosomes in the fully developed parthenogenetic frogs. Thus far the sections of the testes of only one of the writer's parthenogenetic frogs have been examined cytologically. This male was seventeen months old, had reached the full size of the adult, and had large testes with ripe spermatozoa. Prof. R. Goldschmidt, who was good enough to examine some of the sections, counted over 20 chromosomes, and there can be no doubt that this parthenogenetic male frog possessed the diploid number of chromosomes. The writer has not yet been able to ascertain whether the nuclei of the female frogs have the haploid or diploid number.

It is not known whether the female or male is homozygous for sex in the frog. If the female were homozygous it would mean that the haploid number of chromosomes would be $12 + x$ and the diploid $24 + 2x$. In this case only a female could have the diploid number since $2x$ would determine a female. Since we find the diploid number of the male parthenogenetic

frog the assumption of homozygosity of the female is inadequate if not excluded. If we assume that the female is heterozygous for sex, and that it has the chromosome constitution $24 + x + y$ (where y may be missing), the male must have the chromosome constitution $24 + 2x$. The haploid number in the egg would be[5] $12 + x$, and the diploid number either $24 + 2x$ or $24 + x + y$. The diploid number $24 + 2x$ would give rise to a male, while a female might be produced by either the haploid number $12 + x$ or the diploid number $24 + x + y$. It is, therefore, of some interest to find out whether or not the female has the haploid number $12 + x$ chromosomes. It is useless to enter into further speculation until this point is decided, which the writer hopes may be possible in the near future.

Summary.—The author has raised twenty leopard frogs produced by the methods of artificial parthenogenesis from unfertilized eggs to the age of from ten to eighteen months. Nine of these frogs are still alive. Some have reached the size of the full grown normal adult male. Both sexes are represented among the parthenogenetic frogs. Seven of the nine older frogs whose gonads were examined were males, and two were females. The parthenogenetic males possess the diploid number of chromosomes.

[1] Loeb, J., and Bancroft, F. W., *J. Exp. Zoöl., Wistar Inst., Philadelphia*, **14**, 1913, (275); **15**, 1913, (379).

[2] Loeb, J., these PROCEEDINGS, **2**, 1916, (313); *The Organism as a Whole*, New York, 1916.

[3] Swingle, W. W., *Biol. Bull., Wood's Hole*, **33**, 1917, (70).

[4] Brachet, A., *Arch. Biol., Paris-Bruxelles*, **26**, 1911, (362).

[5] The other haploid number $12 + y$ may be left out of consideration for the present since it is possible that such eggs may not be able to develop.

THE RESOLVING POWERS OF X-RAY SPECTROMETERS AND THE TUNGSTEN X-RAY SPECTRUM

By Elmer Dershem

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Communicated by R. A. Millikan, February 11, 1918

This work was undertaken at the University of Iowa with the purpose of determining the wave lengths and the number of lines in the X-ray spectrum of tungsten with greater precision than had heretofore been done.

The method adopted was the well known photographic one in which the crystal is slowly rotated so that it will progressively pass through all the angular positions which are required for reflection of the incident X-rays as demanded by the formula $n\lambda = 2\,d \sin\theta$, in which n is the order of the spectrum, λ the wave length, d the grating constant, and θ the glancing angle of reflection.

Some of the conditions affecting the resolving power of an X-ray spectrometer, that is the ability of the instrument to separate two waves of nearly the same length may be derived by the aid of the diagram (fig. 1).

Assume a source, i.e., a slit, of width s, and a crystal of thickness t and assume that the absorption in the crystal is not so great but that some of the rays may penetrate entirely through the crystal and being reflected from the planes on the lower side again traverse the crystal and finally reach the photographic plate $B'A'C'D'$. It is easily seen that there will be an image on the plate equal in width to the width of the source s, due to reflection from the upper surface alone. In addition there is a widening of the line due to the part reflected from the lower planes equal to the line DE which is drawn from P perpendicular to AA'. Then since $DF = t$ = the thickness of the crystal, $t = AD \sin \theta$ and $AD = DE/\sin 2\theta$ and by substitution $t = DE/\sin\theta = \frac{1}{2} DE/\cos\theta$. Whence $DE = 2t \cos\theta$.

Since DE is the width of beam due to penetration into the crystal the total width of beam is $s + 2t \cos\theta$ and this is the width of line on the photographic plate.

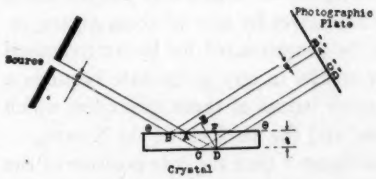

FIG. 1

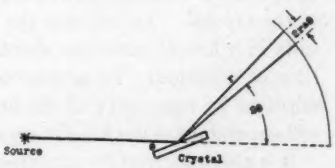

FIG. 2

In order to resolve two lines of nearly the same wave length it is necessary that their images on the photographic plate should not overlap, that is the centers of their images must be further apart than the width of beam, $s + 2t \cos\theta$.

Assume two wave lengths, λ and $\lambda + \Delta\lambda$, then to find how small $\Delta\lambda$ may be and still have the two wave lengths clearly separated on the plate: Using the formula $n\lambda = 2d \sin\theta$ let λ take on a small increment $\Delta\lambda$ and θ the corresponding increment $\Delta\theta$. Then by differentiation we obtain $n\Delta\lambda = d \cos\theta \Delta\theta$.

From figure 2 we see that the angle of the crystal must be changed by the amount $\Delta\theta$ in order to reflect the wave of length $\lambda + \Delta\lambda$ instead of the one of length λ and that the reflected ray being rotated through twice this amount is rotated through the angle $2\Delta\theta$. If the distance from the crystal to the plate is r then the distance the beam has moved along the plate in changing from λ to $\lambda + \Delta\lambda$ is $2r\Delta\theta$ and this distance must be greater than the width of beam, $s + 2t \cos\theta$. Thus

$$2r\Delta\theta > s + 2t \cos\theta$$

But

$$\Delta\theta = \frac{n\Delta\lambda}{2d \cos\theta}$$

Whence

$$\frac{nr\Delta\lambda}{d \cos\theta} > s + 2t \cos\theta,$$

$$\Delta\lambda > \frac{d \cos\theta}{nr}(s + 2t \cos\theta).$$

Defining, as usual, the resolving power to be $\lambda/\Delta\lambda$, we have by dividing λ by each side of the inequality

$$\frac{\lambda}{\Delta\lambda} < \frac{nr\lambda}{d \cos\theta\,(s + 2t \cos\theta)}$$

From this it is apparent that the resolving power may be increased by increasing the order of the spectrum and the distance between the crystal and the plate and also by decreasing the width of the source and the thickness of the crystal. To increase the resolving power by any of these means results in a loss of intensity which must be compensated for by an increased time of exposure. To secure the best results in any given case requires a selection by experience of the best relative values of these quantities which will depend upon the kind of crystal used and the hardness of the X-rays.

It is also apparent by an inspection of figure 1 that the true position of the line on the photographic plate is to be obtained by measuring to the outer or most deviated side of the image and then subtracting one half of the width of the source. This does not in general coincide with the position of the most intense part of the image and since the point of greatest intensity is the one obtained by an ionization chamber method the latter can never give results of the greatest accuracy.

In the experimental work the endeavor was made to obtain as high resolving power and as accurate measurements as possible. A Coolidge tube with a tungsten target was used with a rock salt crystal to obtain the results given in the table. These results are certainly accurate to within 0.1% in the case of the L radiations and 0.8% in the case of the K radiations.

By the use of a crystal of rock salt which was first waxed to glass and then ground to a thickness of 0.019 cm. the widening of the K lines due to penetration into the crystal was reduced to such an extent as to cause the doublets to be clearly separated in the spectrum of the first order and this is not possible if the thickness of the crystal is not limited.

In the case of the L group of lines the resolving power as defined by the above formula was less than 170 but nevertheless 19 separate and distinct lines were obtained and this very naturally suggests that if it were possible to obtain such resolving powers in X-ray spectroscopy as have been obtained in

The Tungsten X-ray spectrum

GLANCING ANGLE OF REFLECTION FROM ROCK SALT	WAVE LENGTH IN ÅNGSTROM UNITS	REMARKS
	Lines of the L group	
15° 16.3′	1.482[8]	Weak
15° 9.9′	1.472[2]	Strong
14° 34.5′	1.416[3]	Very faint
13° 19.9′	1.297[7]	Medium
13° 13.1′	1.286[8]	Very faint
13° 7.7′	1.278[4]	Strong
12° 54.4′	1.258[6]	Medium
12° 44.6′	1.241[0]	Strong
12° 31.3′	1.220[2]	Very faint
12° 24.8′	1.209[8]	
12° 4.5′	1.177[3]	
11° 34.4′	1.129[2]	Weak
11° 13.3′	1.095[3]	Strong
10° 57.9′	1.070[6]	Faint
10° 54.3′	1.064[8]	Medium
10° 50.5′	1.058[7]	Medium
10° 40.6′	1.042[7]	Very faint
10° 29.8′	1.025[3]	Medium
9° 22.0′	0.915[9]	Bromine absorption line
7° 12.9′	0.706[8]	Medium
4° 55.5′	0.483[3]	Silver absorption line
	Lines of the K group	
2° 9.7′	0.212[4]	Strong
2° 6.8′	0.207[6]	Strong
1° 52.0′	0.183[4]	Strong
1° 49.0′	0.178[4]	Medium

the case of light by the aid of the grating and echelon the number of characteristic X-ray lines would be found to be as great as the number of light spectral lines are now known to be.

Many thanks are due to Professor Stewart and the Staff of the Physics Department of the University of Iowa where this work was performed for assistance in this research.

NOTE ON METHODS OF OBSERVING POTENTIAL DIFFERENCES INDUCED BY THE EARTH'S MAGNETIC FIELD IN AN INSULATED MOVING WIRE

By Carl Barus and Maxwell Barus

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Communicated January 24, 1918

In *Science*, **45**, 1917, p. 270, it was shown that the current induced in a rod about a meter long by the earth's vertical magnetic field, could be made surprisingly evident by the aid of an ordinary galvanometer, synchronized with the period of the inductor pendulum, of which the rod acts as the bob of a bifilar metallic suspension, including the galvanometer. Thus with a galvanometer showing but 10^{-6} amperes per cm. of deflection, and with a common period of about 4 seconds, the double amplitude of the spot of light reached over 20 cm. per average knot of speed of the rod. Similar results must be obtainable in case of a ship, where the charges accumulating at the ends of a long transverse rod may be tapped off into the water; or in case of a train where the tracks are available for dissipating charge. If, however, the rod is insulated, the determination of the potential difference in question is quite difficult. We made many attempts, as for instance the dissipation of charge from the ends by radium, electric incandescence, etc., the magnetic screening of parts of a circuit, etc., all to no practical effect. It seemed necessary therefore to carry the charge from end to end of the wire bodily; i.e., to reverse the principle of any type of induction electric machine, possibly with the additional object of securing intensification. Here also we have no ultimate success to record; but the secondary results are not devoid of interest, the idea being to construct, with precision, a large intensifier to pick up whatever electrostatic potentials may momentarily or permanently exist in the vicinity.

Simple Apparatus.—The apparatus (fig. 1), producing current is essentially cylindrical in shape, large and capable of revolving around an axle a with considerable speed. The electrical parts are of light metal, all insulated or screwed firmly to insulating discs attached to the axle. This frame work will not be shown in the figures.

A, A', A'', A''' are four insulated plates adjusted like the staves of a barrel, each making up about $\frac{1}{4}$ of its cylindrical area. Hence if the diameter of the barrel is D and its length L the area of each segment is $A = \pi LD/n$, if there are n segments. The plates A, communicate by means of metallic rods s, s', s'', s''', with the commutator segments or posts c, c', c'', c''', each system, A, s, c, etc., being insulated.

When the barrel revolves, a pair of brushes $b\ b''$ serve to put the two segments $A\ A''$ momentarily in contact when in the horizontal position. A

similar pair of brushes b' b''' put the segments A' A''' momentarily in contact when in the vertical position. These brushes lead to the inclosed sensitive galvanometer G. Hence there will be two contacts for each pair of segments A for each rotation. B, B' are auxiliary insulated armatures and here removed.

Let the earth's vertical field be H and suppose the corresponding insulated metallic spokes s s'' in contact through b b''. Suppose the barrel to move forward as indicated at v in the direction of its axis, i.e., out of the diagram. Then there will be an induced electric field F in the direction A'' s'' s A, due to the cutting of the earth's vertical field. The result of the momentary contact is thus a positive charge q on A and an equal negative charge on A''.

When as a result of the rotation of the drum around its axis, the segments reach the position A' A''' electromagnetic induction ceases and the field F from this source is zero. Hence on momentary contact the charge will pass through the galvanometer G. With continued rotation this process is indefinitely repeated, so that a nearly continuous current flows through G; but there is no intensification.

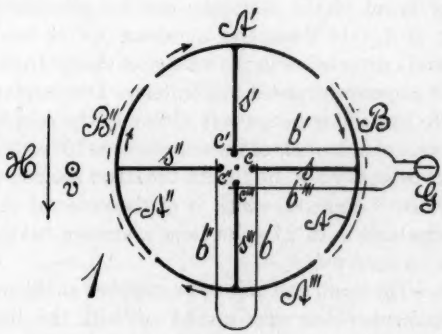


FIG. 1

Elementary Estimate.—Let the drum move in the direction of its axis with a speed v, so that the spokes $s + s'' = D$ cut the earth's vertical field H at this rate. Hence if the difference of potential between the plates A and A'' is V, when c and c'' are in contact

$$V = HDv \text{ elm. units.} \tag{1}$$

Again when c and c'' are insulated A and A'' may be considered the plate of a condenser and so long as the field within may be considered as virtually uniform, we may estimate by Gauss's theorem

$$q = \frac{AV}{4\pi D} = \frac{A}{4\pi}\frac{Hv}{3 \times 10^{10}} \text{ electrostatic units} \tag{2}$$

where q is the positive charge on the area A. Finally if the drum rotates

around its axis a with the speed of N turns per second and if there are n segments, A, the corresponding mean current passing through the galvanometer, with inclusion of the value of A above, on reducing to practical units will be

$$I = NDLHv/3.6 \times 10^{20} \text{ amperes} \qquad (3)$$

Let $N = 100$; $D = 100$ cm.; $L = 100$ cm.; $H = 0.4$ dynes per unit pole; $v = 50$ cm./sec. or about 1 knot. Then

$$I = \frac{10^2 \times 10^2 \times 10^2 \times .4 \times 50}{3.6 \times 10^{2D}} = 5 \times 10^{-14} \text{ amperes, nearly.}$$

i.e., the current traversing the galvanometer per knot of axial motion through the earth's vertical field would scarcely be perceptible by an extremely sensitive galvanometer.

In our trial of the apparatus we used a disc pattern like figure 3, putting both a galvanometer and a telephone in series, at G. On charging auxiliary armatures like B, B'' in figure 1, with a small Wimshurst machine, a loud rattle was immediately heard in the telephone and the galvanometer showed an average current of 2×10^{-6} amperes at about 10 (or less) rotations per second. This slowly dropped owing to leakage of charge from the armatures; but at least 10^{-6} amperes persisted indefinitely. Discharging the armatures was followed with immediate permanent silence in the telephone. If we estimate the difference of potentials of the armatures as 10^4 volts, and the earth's field H (as above) to supply 5×10^{-5} volts, the latter should produce 5×10^{-5} $(2 \times 10^{-6}/10^4) = 10^{-14}$ amperes, which is of the order of values computed. Charging the armatures with 25 volts from a storage battery produced no result, as was to be expected.

Intensification.—The drum was now to be modified as suggested in figure 2, though the experiments below were carried out with the disc form, figure 3, which is more easily constructed. All contacts must be synchronous and momentary.

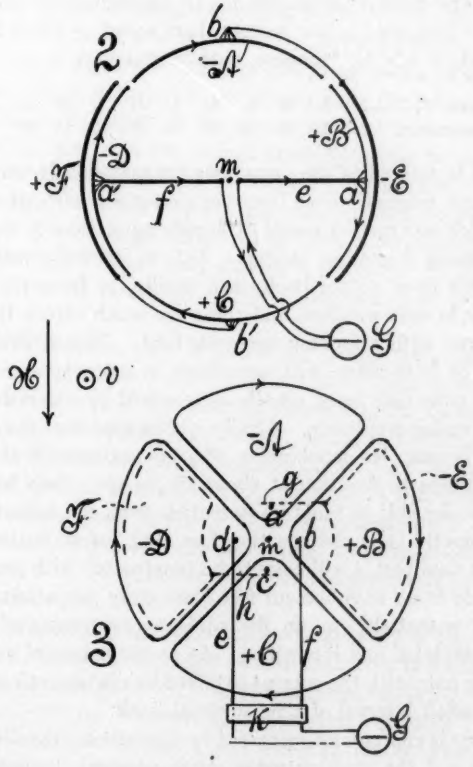
In the disc type of machine (fig. 3) (as here constructed about 2 feet in diameter), A, B, C, D (in front) are the segments, rotating around the axis m, and E, F the armatures behind the diagram. The metallic posts or commutators a, b, c, d stick out normally from the disc both in front and behind it. The vertical brushes d and b touching diametrically opposite posts in front successively, include the galvanometer, etc., G, K being an insulating holder. The horizontal brushes, g and h, in metallic connection with E and F, respectively, touch the other two posts successively behind the disc and store the charges of A and C on E and F. H shows the earth's magnetic field and v the motion through it.

If we suppose that any charge on the armature E, for instance, induces the same but opposite charge on the segment B, the charges successively passing through the galvanometer for each quarter turn may be scheduled in

such a way that the sum is a geometrical progression. Thus for N turns $Q = \Sigma q = (4/5)k^N q$ coulombs, nearly, where k is a large empiric constant depending on the method of initial charging and on the effective capacity of the armature-quadrant condenser.

Finally if there are N turns per second and $n = 4$ segments, the average current is in the first second:

$$I = k^N DLHv/1.8 \times 10^{21} \text{ amperes.}$$



FIGS. 2 AND 3

Thus even if $N = 10$ turns for 1 second, 20 turns for 2 seconds, etc., the current would soon be appreciable.

Observations with the Intensifier.—The telephone and galvanometer may be inserted together and their indications as to intensity are identical; but the galvanometer additionally shows the sign of the current. The average current of 10^{-7} amperes could still be easily heard in the telephone. The elec-

troscope and electrometer were also tested; but these instruments are unsuitable as on open circuit the potential may suddenly rise to sparking values and ruin them.

Great care was taken to secure all insulators *firmly* and to allow only metal appurtenances (brushes) to touch each other.

The sounds (taps) were usually strong on starting the intensifier. As the speed increases to about 5 or 10 rotations per second a maximum of current was reached. This may be an average current of $\pm 10^{-5}$ amperes or more, as specified. The current frequently has an approximately regular period of reversal; as for instance (L, low current, here about -2.5×10^{-6} amperes; H, high current, $+5 \times 10^{-6}$ ampere, both fluctuating).

Successive currents.....	L	H	L	H	L	H	L	H	L	H	L	H, etc.
Period of each (seconds).....	25	30	30	30	30	35	45	35	40	35	45	35 etc.

The current is zero when the armatures are metallically connected. This shows that stray magnetic lines from the motor are without *direct* effect, a conclusion which was further tested by supplying stationary looped magnetic lines from a strong horseshoe magnet. Left to itself the machine picks up potentials either from within itself, incidentally, or from the room or sursounding walls in cold weather; and these are much higher than any which can be produced with a moving magnetic field. The machine, thoroughly flame-cleaned on both sides, with armatures in contact, soon charges itself, the maximum potentials being usually approached by successive alternations of rapidly increasing amplitude. Finally sparks appear at the brushes. If a bunsen flame is near, its depolarizing effect is appreciable at about a foot; the machine ceases to function at about six inches. Only under favorable conditions were we able to build up potentials from the induction of a small horseshoe magnet. It is obvious therefore that before putting such an apparatus to the final test it will have to be constructed with precision and experiments made in an environment free from stray potentials, with elimination of voltaic potentials, etc., in the parts, as everything of this nature is so quickly assimilated and intensified. As to the means of rating the value of the inducing potential, the current obtained on disconnecting the armatures for a definite small interval of time suggests itself.

The efficiency is enormously increased by diminishing the distance between the armatures and the rotating segments (condenser) though in the above improvised apparatus it was not possible to approach closer than an average half inch.

DEPENDENCE OF THE SPECTRAL RELATION OF DOUBLE STARS UPON DISTANCE

By C. D. Perrine

Observatorio Nacional Argentino, Córdoba

Communicated by E. B. Frost, January 7, 1918

In the course of an investigation of the cause of the spectral differences of the stars, an examination of the spectra of the components of double stars was made. Almost at once it was seen that there was a relation other than the well known conclusion that in contrasted pairs the fainter component is generally of the earlier type. It was found that such stars are almost invariably very distant, and that the reverse generally occurs in the near pairs.

The principal data used in this investigation were taken from the observations of the spectra of 745 double stars made at Harvard and classified by Miss Cannon.[1] Seventy-eight stars were selected of which the spectra of both components had been determined, having a difference of brightness of at least half a magnitude and known to be either binary or to have common proper motion.

It was noticed that the stars in which the fainter component was of the earlier type were, in general, closer together than those in which the companion was of a later type. The effect of distance on the separations of these stars was investigated by means of proper motion. The result indicated a greater average absolute separation in both classes than for the stars whose magnitudes and spectral classes are nearly the same. Incidentally, however, it was shown that the pairs in which the fainter component is of earlier type are distant, whereas those in which the fainter companion is of later type, with the exception of the stars both of whose components are of classes B and A, are much nearer.

Of the stars selected, 24 have the fainter components of the same spectral type, 26 have the fainter components of later and 28 of earlier spectral type. The last two groups are given in detail in the tables following.

With the exception of the pairs (12 in number) of table 1, which have *both components of classes B and A* and whose proper motions are less than 0″.05, the remainder show large differences of spectral type and large average proper motion. It is to be noted that 4 of the 12 stars with small μ in this table, having the fainter component of *later* type, belong to 15 Cephei. The consistency in the spectral relations of this group is noticeable.

The pairs of table 2, with two exceptions, show small proper motions. The proper motions of these two stars cannot be said to be large and it is further to be noted that their differences of spectral type are rather small. The

[1] *Ann. Harvard Coll. Obs., Cambridge*, **56**, no. 7.

average μ of the entire 28 stars is but 0″.037, or omitting the largest two, is but 0″.030. The criterion of proper motion, therefore, indicates that these stars are at the same general distance as the class B stars.

The stars of table 2 also show a decided preference for the galaxy, half of them being within 15° and three-quarters of them within 40° of the galactic plane. This is significant when it is considered that the principal stars of these pairs belong almost entirely to the middle and later types of spectra.

TABLE 1

FAINTER COMPONENT OF LATER TYPE

MAGNITUDE BRIGHTER COMPONENT	Δ MAGNITUDE	SPECTRAL CLASS		μ	s
		Brighter	Fainter		
5.6	0.9	A_5	G_5	0″.143	23.″7
5.2	2.6	F_5	G	.295	49.4
6.0	0.7	A_0	A_2	25	16.6
3.0	3.3	B_8	A_0	52	117.3
4.9	0.6	B_8	A_0	82	7.8
1.3	6.3	B_8	G	.247	176.7
5.3	1.8	F_0	G_0	.289	288.1
5.4	1.4	A_0p	A_2	29	145.3
0.3	1.4	G_0	K_5	3.67	21.9
2.9	2.2	A_2	F_5	.131	231.0
4.5	2.2	F_0	K_0	.169	108.3
4.3	2.2	B_3	A	34	41.3
4.9	2.7	A_2	F	65	88.8
6.0	0.6	B_8	A	38	21.7
5.8	0.8	B_3	A	22	35.7
4.6	1.9	A_3	G?	.230	6.9
5.8	0.7	B_3	B_8	18	22.4
3.6	2.5	A_5	K_0	.107	337.1
4.8	2.7	B_8	A	10	22.8
Var. 3.4	4.4	B_2	B_3	8	46.0
6.7	0.9	B_0	B_9	13	183.4
6.8	0.8	B_5	B_9	13	136.1
6.7	0.1	B_0	B_5	13	236.3
6.8	1.0	B_5	B_9	13	192.4
4.2	1.7	B_9	A_0	.121	26.9
4.8	4.8	Ap	K	.138	222.8

Further evidence is found in 19 of the Harvard stars which have composite spectra and in 62 stars of Campbell's Catalog of Spectroscopic Binaries,[2] in which the spectra of both components have been observed or strongly suspected.

For both spectra to appear on a photograph, the difference in brightness of the components of close binary stars will usually be small. On account of the tendency for components of nearly the same brightness to have similar

[2] *Lick. Obs. Bull., Berkeley*, 6, 1910, (46).

spectra, the evidence from these two sources is not of as great weight as the preceding. It is, nevertheless, quite definite.

Of the 19 Harvard composite stars, two are somewhat uncertain as to the difference of spectral class, both being of early type. Of the remainder, the one having the largest proper motion (0″.15) has the fainter component of the later type. The remaining 16 all have very small proper motions. Of these, 5 have the fainter component of later type and 11 of earlier type. All of

TABLE 2

FAINTER COMPONENT OF EARLIER TYPE

MAGNITUDE BRIGHTER COMPONENT	Δ MAGNITUDE	SPECTRAL CLASS		μ	s
		Brighter	Fainter		
6.2	1.2	G_0	A	0″.018	2″.9
4.3	0.9	A_3	A	42	2.6
2.3	2.8	K_0	A	70	10.7
5.0	1.4	G_5	B?	34	6.9
5.5	1.2	G	A_3	29	3.0
5.9	1.1	A_0	B_9	27	28.9
5.8	1.2	G	A	47	0.4
5.4	3.1	K	A	7	2.3
3.9	1.9	K_0	G	97	13.3
6.4	0.5	G	A_2	41	63.4
4.2	2.4	G_5	A_2	54	30.6
5.2	1.5	K_0	A_3	17	20.6
5.3	0.5	A_2	A	33	21.6
2.7	2.4	K_0	A	49	2.8
3.5	4.5	K_0	G_0	155	104.8
1.2	5.8	Ma	A	34	3.2
6.4	1.1	K	F_5	48	111.2
6.1	1.7	G	A	11	45.5
5.6	1.2	F_5	A	13	0.6
7.1	1.0	G	A	42	4.1
6.0	1.5	F_5	A_3	18	15.0
3.2	2.1	K	B_9	9	34.7
5.6	3.3	K_0	A	34	19.8
6.5	1.1	F	A	Small	1.2
5.7	2.2	G_0	A	20	89.9
6.1	0.	G_5	A_2	25	23.0
3.9	3.2	K	B_8	2	107.1
3.3	2.8	G_0	A_0	28	205.2

the most strongly marked spectral contrasts have the fainter components of earlier type and all but one of these 11 are well marked in respect to spectral contrasts.

Of the 62 stars of Campbell's Catalog, 30 belong to types O and B and 23 to type A. It is reasonably certain, therefore, that all of the O and B stars are distant and the probability is strong that most of the 23 stars of type A

are distant also. Campbell concludes,[3] I understand, that the rule that when one spectrum is considerably fainter than the other, the spectrum of the secondary is apparently of a slightly earlier type than the spectrum of the primary, applies to these stars, which we have just found to be distant.

Both of these pieces of evidence are confirmatory of the condition previously found.

I have also examined several well known systems whose colors have been observed, viz., α Herculis, η Geminorum, γ Delphini, η Cassiopaeiae, ξ Boötis, β Cephei and γ Leonis. These stars also show in general the same relation to distance.

Careful consideration of the data seems to show beyond doubt that the relation is to distance coupled with low galactic latitude. It cannot well depend upon the actual separations of the stars, for the ranges in that respect seem to be about the same in all of the groups. It can scarcely depend upon the differences of mass of the conponents as indicated by their differences of brightness, for a similar reason. There is a difference of absolute magnitude between the two groups, but there seems to be no reason for suspecting a relation in this case, whatever may be the bearing of such differences in others.

It is not known whether both components of double stars were originally of the same spectral type or not. Investigators have generally assumed that they were. It is not possible to say, therefore, just what the course of change has been. However, we may justly conclude, I think, that the conditions are such in these regions as to produce *opposite* spectral effects in the components. There can be little doubt that the fainter components are in general also of smaller mass. The conclusion may be stated, therefore, in the following form:—The conditions appear to be such that if two stars of unequal mass were introduced into the near region the smaller body would move more rapidly toward the later stage than the larger one, whereas in the relatively distant galactic regions the tendency would be for the smaller body to become of *earlier* type more rapidly than the larger one.

This investigation also shows that the greatest differences in spectral type are in general found among the stars whose components show the greatest differences in brightness. The differences of brightness in the pairs having the same spectra are consistently small for all types.

The results of this investigation seem to indicate with considerable force that some external cause is operating in more or less definite regions of our stellar system upon the conditions which produce spectral class.

The details have been given more fully in a paper which will be published in the *Astrophysical Journal*.

[3] *Ibid.*, 6, 1910, (47).

HYPOTHESIS TO ACCOUNT FOR THE SPECTRAL CONDITIONS OF THE STARS

By C. D. Perrine

Observatorio Nacional Argentino, Córdoba

Communicated by E. B. Frost, January 7, 1918

The peculiar behavior of double stars in the near and relatively distant regions of the galaxy, which has just been discovered (these Proceedings, **4**, 1918, 71), together with the well known preference of the stars of type B for the Milky Way and the general preference of the later types for the nearer regions of space, suggest the conclusion that spectral class depends largely upon external causes.

Further study of the brightnesses and spectra shows that there is a strong similarity between the brighter stars of early type if arranged in the order B, O, gaseous nebulae, and the changes in the novae in their early stages. As is well known, all of these objects are confined to relatively distant regions in the direction of the galaxy. There is also reason to think that the same cause which is believed to underlie the phenomena of the outbursts in the novae may be a vital factor in the determination of spectral class among the ordinary stars.

As a result of these investigations the following general hypothesis has been formulated to account for the present classes of stellar spectra.

Hypothesis.—The cause is dual, depending upon the amount of cosmic matter and upon phenomena of radiation and condensation. Many of the A stars, the B and O stars, the planetary and irregular gaseous nebulae, the novae and perhaps the Cepheid variables, are confined to the galaxy because there the matter is sufficiently plentiful to cause an increase of energy, the energy from the matter swept up being in excess of that lost by radiation. The direction of spectral change under such conditions in *toward the nebulae.*

In the regions (distant or near) where there is little or no cosmical matter, radiation will be in excess of the energy received from external sources and the direction of change will be *toward the late types.*

In a considerable portion of the system the changes of spectral class may be due simply to retardation.

The hypothesis may be further generalized as follows—

The spectral condition of a star depends chiefly upon its size and mass and the external conditions of density of cosmical matter and relative velocities of star and matter.

Upon this hypothesis the stars are probably all pursuing one definite course of very slow change toward extinction, but each individual star will be pursuing a course which may have many whole or partial cycles due to varying external causes.

Details of this investigation are given in a paper which has been sent to the *Astrophysical Journal.*

NATIONAL RESEARCH COUNCIL

MEETINGS OF THE EXECUTIVE COMMITTEE

THIRTY-FOURTH MEETING—DECEMBER 4, 1917

The meeting convened in the offices of the Council in the Munsey Building, Washington, D. C., and was called to order at 9.15 a.m. by the Chairman, Mr. Hale.

Messrs. Marston T. Bogart, Russell H. Chittenden, George E. Hale, Arthur A. Noyes, Raymond Pearl, S. W. Stratton, Charles D. Walcott, and, by invitation, W. F. Durand and Charles E. Mendenhall were present.

The minutes of the meeting of the Committee of November 10 were approved as prepared and submitted to the members of the Committee.

The Chairman of the Council reported:

1. That Col. P. D. Lockridge, Acting President of the Army War College, and Capt. Roger Welles, Director of Naval Intelligence, U.S.N., have been appointed members of the Council and of its Military Committee.

2. That at a recent meeting of the Military Committee the request of the British Ministry of Munitions, and a later communication from the British War Mission, relative to the organization of an experimental liaison were considered, involving the appointment of a competent group of American scientists to secure adequate intercommunication between English and American industrial and military projects and development. This request was cordially received and approved, having already received the approval of the Executive Committee. A full discussion of the subject at meetings of the Military Committee, however, led also to the approval of the organization of a more extensive program, involving intercommunication between the entente allies on all subjects of industrial and scientific importance. A subcommittee, consisting of the Director of the Bureau of Standards, the Acting President of the Army War College, and the Director of Naval Intelligence, was appointed to submit recommendations with regard to the procedure necessary to establish this liaison, under direct authority of the War and Navy Departments of the Government.

A financial statement, showing expenditures since the last monthly meeting of the Committee, was submitted and approved.

Upon recommendation of the Vice-Chairman of the Engineering Committee, the following were added to the membership of this Committee:

Comfort A. Adams, Harvard University; Jesse Coates, Consulting Engineer.

Mr. Durand reported for the special committee, consisting of himself and Messrs. Millikan and Stratton, which was appointed to undertake the selection of a larger committee to consider the organization and various problems of the Patent Office. As a result of discussion the following members of such a committee were appointed:

Leo H. Baekeland, William F. Durand, Thomas Ewing, Frederick P. Fish, Robert A. Millikan, Edwin J. Prindle, Michael I. Pupin, S. W. Stratton.

Upon recommendation of the Chairman of the Chemistry Committee,

Lieut. Col. Wm. H. Walker was added to the membership of this Committee and Frederick W. Brown, of the Bureau of Soils of the U. S. Department of Agriculture, was named a member of the Subcommittee on Chemistry of Soils and Fertilizers.

The Chairman of the Chemistry Committee also reported that a donation of $100 a month had been received from B. T. Bush of the Antoine Chiris Company of New York to assist the work of this Committee. Upon motion, the Executive Committee tendered a vote of thanks to Mr. Bush for his co-operation and financial assistance in this connection.

The Chairman of the Council reported upon conferences which had been held relative to the organization and work of the proposed Forestry Committee and submitted for consideration a list of persons who might be favorably considered for appointment as members of the Committee. After discussion it was voted that a special committee, consisting of Irving W. Bailey, Raymond Pearl and Karl F. Kellerman, be appointed to consider the organization and duties of the Forestry Committee of the Council as a correlating agency for research in this field and to submit to the Executive Committee recommendations with regard to the personnel of the Forestry Committee, the proposed scope and functions of this Committee, and its status in the general organization scheme now under consideration relative to the future activities of the Council.

Mr. Stratton, for the Subcommittee of the Military Committee, appointed to submit recommendations with regard to procedure necessary to establish a scientific liaison between the entente allies, submitted a report with recommendations which had been adopted by the Military Committee at its meeting of December 3. These recommendations were considered carefully by the Executive Committee and, after certain minor modifications, were adopted as follows:

In order to facilitate the securing and dissemination of scientific and technical industrial information for military purposes, the Military Committee of the Research Council recommends as follows:

1. There shall be a committee known as the Research Information Committee, to consist of the Chief of the Military Intelligence Section of the Army, the Director of the Naval Intelligence Bureau of the Navy, and a representative of the National Research Council to be nominated by the Chairman of that body and appointed by the Council of National Defense, who shall be Chairman of the Committee.

2. A scientific and technical industrial representative of the National Research Council shall be attached to the offices of both the Naval and Military Intelligence in London, Paris, and such other countries as may be considered desirable, and the said representative together with the said military and naval attachés shall form a committee at each station acting as a subcommittee of the Research Information Committee.

3. The duties of this Committee shall be to provide for the collection of scientific and technical industrial information relating to military and naval affairs at home and abroad and for the dissemination of the same to the Governmental departments interested both at home and abroad.

4. This Committee shall be provided with a permanent secretary, and with the clerical

and office facilities requisite for such files, indices and correspondence as the Committee may direct.

5. In addition to the usual duties in connection with the keeping of files, indices, conduct of correspondence, and so forth, the especial duty of the Chairman of the Committee shall be to assist the proper officials in securing, locating, and disseminating the information required, under such rules and regulations as the Committee may formulate from time to time.

6. When scientific and technical industrial information is required which involves investigation to be made in coöperation with foreign civil authorities or military authorities not at the front, the investigators selected shall be duly vouched for by this Committee and shall be accredited by it to the Research Information Committee abroad.

Upon motion of Mr. Noyes it was voted that these recommendations be transmitted to the Council of National Defense with such additional details relating to the cost and organization of the proposed liaison as may be formulated by the subcommittee of the Military Committee in consultation with the Chairman of the Council.

The Chairman of the Council reported that the Committee on Organization had tentatively considered a scheme for the organization and future development of the Council, copies of which were laid before members of the Executive Committee. Extended discussion took place, after which it was decided to hold another meeting of the Executive Committee in the near future to continue such consideration.

The Chairman of the Council was requested to appoint a special committee to consider the acquisition of adequate office accommodations in Washington.

The meeting adjourned at 1.30 p.m.

THIRTY-FIFTH MEETING, DECEMBER 19, 1917

The meeting convened in the offices of the Council, Munsey Building, Washington, D. C., and was called to order at 9.15 a.m. by the Chairman of the Council, Mr. Hale.

Marston T. Bogert, Russell H. Chittenden, Edwin G. Conklin, Gano Dunn, George E. Hale, Van H. Manning, R. A. Millikan, Arthur A. Noyes, Raymond Pearl, S. W. Stratton, Victor C. Vaughan, Charles D. Walcott, and, by invitation, William F. Durand and John C. Merriam were present.

The Chairman of the Council reported:

1. That arrangements have been made to lease the building at 1023 16th Street, Washington, D. C., for the offices of the Council, at a rental of $500 a month, and that a statement of estimated office expenses of the Council, aggregating $29,250.00, for the year 1918, has been submitted to the Director of the Council of National Defense.

2. That the resignation of Mr. Mendenhall as Chairman of the Committee on Relations with State Research Councils has been accepted and that Mr. Merriam, of the University of California, has been appointed Chairman of this Committee.

Upon suggestion of the Chairman, Mr. Merriam reported upon the proposed scope and organization of the Committee on Relations with State Research Councils. Upon motion the Committee on Relations with State

Research Councils was requested to submit a report to the Executive Committee as soon as practicable, with recommendations concerning steps to be taken to affiliate and closely coordinate the work of State Research Councils with that of the National Research Council.

In extension of the discussion which took place at the meeting of the Executive Committee on December 4 relative to the reorganization and future development of the Council, Mr. Hale spoke of the rapid extension of its work and particularly of the importance of its Military Committee and of its governmental associations, as well as of the necessity of basing any future scheme of organization on the charter of the National Academy of Sciences, as an official advisor of the Government.

A proposed plan of organization was laid before the Committee and tentatively adopted as a basis for further consideration and discussion.

Mr. Dunn explained that the Engineering Foundation had expressed its willingness and desire to furnish financial assistance in aid of researches which might advisedly be undertaken by the National Research Council in the field of engineering, and upon his suggestion, as Chairman of the Engineering Committee of the Council, it was voted that the Executive Committee request the Engineering Committee to submit suggestions to the Engineering Foundation with regard to financial needs for problems in engineering research.

The meeting, which adjourned at 11.40 a.m., was followed by two sessions of a joint meeting of the Executive Committee of the Research Council and of the Council of the National Academy of Sciences, at which discussion took place with regard to the proposed organization of the Research Council and its relations to the National Academy of Sciences.

THIRTY-SIXTH MEETING, JANUARY 17, 1918

A joint meeting of the Council of the National Academy of Sciences and of the Executive Committee of the National Research Council convened at 9.30 a.m. in the offices of the Research Council at 1023 16th Street, Washington, D. C., with President Walcott of the National Academy of Sciences in the chair.

Present: Members of Council of National Academy of Sciences: Russell H. Chittenden, Whitman Cross, George E. Hale, William H. Howell, Charles D. Walcott. Members of Executive Committee of National Research Council: Marston T. Bogert, Russell H. Chittenden, George E. Hale, Van H. Manning, Robert A. Millikan, S. W. Stratton, Charles D. Walcott, William H. Welch. Also present by invitation: William F. Durand, Simon Flexner, Charles E. Mendenhall, John C. Merriam, Robert M. Yerkes, and William H. Walker.

The Chairman of the Council reported:

1. That an allotment of $29,250 has been authorized, by the President of the United States, from the emergency appropriation at his disposal to apply toward the estimated office expenses of the National Research Council for the year 1918.

2. That the building at 1023 16th Street has been rented by the Research Council, and that the twenty-two rooms in the building have already been assigned to provide for the growing activities of the Council.

3. That in accordance with the action of the Executive Committee at its meeting on December 4, the proposed recommendations with regard to the organization of a Research Information Committee have been submitted to the Council of National Defense. These recommendations were approved, and authority issued for the establishment of three committees to inaugurate the proposed work. The Committee in the United States consist of S. W. Stratton, Chairman, representing the National Research Council; Captain Roger Welles, Director of Naval Intelligence, U. S. N.; and Colonel Ralph H. Van Deeman, Chief of Military Intelligence Section, Army War College. The London Committee will consist of Henry A. Bumstead of Yale University, representing the National Research Council, together with representatives of the Army and Navy Intelligence Services to be appointed; and the Paris Committee will consist of William F. Durand, Vice Chairman of the Engineering Committee of the National Research Council, representing the Council, with representatives of the Army and Navy Intelligence Services to be appointed. The State Department has agreed to appoint Mr. Bumstead and Mr. Durand as Scientific Attachés of the Embassies at London and Paris respectively. Mr. Harold D. Babcock, a physicist at the Mt. Wilson Solar Observatory, has been appointed Technical Assistant of the Washington Committee, and it is expected that he will report for duty on January 21, with offices in the National Research Council building. A request has been made of the Council of National Defense for funds to provide for the expenses of these three offices. Mr. K. T. Compton of Princeton University has been appointed Technical Assistant of the Paris committee.

The resignation of Cary T. Hutchinson as Secretary of the National Research Council was presented and accepted,

The resignation of Raymond Pearl as Chairman of the Agriculture Committee of the Council was presented and accepted.

Upon nomination of the Chairman of the Council, John Johnston, at present in charge of the offensive gas warfare work of the U. S. Bureau of Mines, was elected Executive Secretary of the National Research Council at an annual salary of $5000, to take effect as soon as Mr. Johnston is able to accept the appointment and devote his entire time to the work of the Council.

Upon recommendation of the Chairman of the Chemistry Committee, the following subcommittee was appointed with Chairman as indicated:

Sub-Committee on Chemical Engineering: Chairman, Charles F. McKenna, 50 Church Street, New York City.

The appointment of the Sub-Committee on Chemical Engineering was requested by the American Institute of Chemical Engineers, and the Chairman was nominated by the Institute.

The Chairman of the Chemistry Committee also reported that:

William J. Comstock, formerly of the Chemical Staff of Yale University, has come to Washington to aid in the work of the Chemistry Committee, to which he will devote his entire time, and that

The Chairman of the Chemistry Committee has been made a member of an Advisory Committee of the War Trade Board.

Upon nomination of the Chairman of the Council, Charles B. Davenport was appointed Vice-Chairman of the Anthropology Committee.

Mr. Merriam, Chairman of the Committee on Relations with State Research Committees, presented the following report:

It is the opinion of your committee that the greater part of the problem work of the National Research Council can be handled most satisfactorily through the special committees or divisions established for research in specific fields of investigation. To a limited extent phases of these investigations of problems may be turned over to adequately organized and supported research groups in different parts of the country, some of these groups representing educational or research institutions and others being organized under the auspices of state governments or state Councils of Defense.

As numerous important problems of research relate to the development of natural resources, industries, consideration of health conditions, and other problems of a local nature, it seems desirable in many cases to have an organization of research interests related to the state, and if possible supported by it. Such organizations might, under existing conditions, be best cared for as committees under the state Councils of Defense.

It is desirable to have the National Research Council so related to the state research scientific committees that the results of their investigation may become quickly available to the central office of the Council, and that the needs of the Council for work of a local character may be met by the state committees.

Your Committee respectfully suggests the following definition of function, organization, and relations of State Research Committees:

Function of State Research Committees. Problems involving local needs in the development of natural resources, local industries, health conditions, or any matters to which science may lend its aid; and problems involving local materials, industries, laboratories or talent, development or use of which would contribute to the good of the nation as a whole or in part, regardless of questions of needs of the state in which the investigation originates.

Organization of State Committees. In initial organization the state committee should be small, but widely representative of fields of research. Additions to membership should be made as actual research progresses. The committees should, at the outset, include members of state boards covering work in which scientific research plays an important part, and representatives of scientific organizations or institutions at which significant research is in progress, especially institutions in which research committees are organized.

State research committees should at this time be organized as sub-divisions of state Councils of Defense, where such councils exist.

Financial support of state committees should come from state funds received by way of the state Councils of Defense, or from other special funds. It is in all cases desirable to have secretarial organization permitting full correspondence on all matters relating to the committee.

Relation of Research Council to State Committees. It is desirable to have the state research committees affiliated with the National Research Council; the results of work of these committees should be reported to the state Council of Defense and to the National Research Council by way of either or both of these bodies; results obtained by the state research committees should go to the Council of National Defense when needed.

It was voted that the above report be adopted as furnishing the mode of procedure to be used by the National Research Council in directing its relations to state research committees.

The Chairman of the Council spoke at length with respect to the adoption of an organization of the Council devised to meet immediate war needs. The present organization, adopted in 1916 for a period of one year, is essentially a peace organization. Under war conditions the Council is engaged almost

exclusively in scientific and research work for the Army, Navy, War Industries Board, and other Government bodies, and the wide distribution of the members of its committees has been a source of inconvenience and sometimes of confusion. Such a war organization would involve the concentration in Washington of comparatively few men representing the most essential work.

For convenience of operation, it is proposed that closely related subjects be grouped in Divisions, to avoid such difficulties as have sometimes arisen from the independent work of committees covering similar fields. The Executive Committee of each Division is, in general, to be composed of the smallest possible number of representative men, living in Washington or closely in touch with the work of the Government.

All of the old committees of the Council will remain in existence, to be called upon for such work as the various Divisions may assign to them.

He then submitted to the members present a schedule of the proposed war organization of the Council, which after discussion and upon motion was adopted, as follows:

WAR ORGANIZATION OF THE NATIONAL RESEARCH COUNCIL

General Officers: Chairmen, Three Vice-Chairmen, Executive Secretary, Treasurer, Assistant Secretary.

Executive Board: General Officers, the Chairmen and Vice-Chairmen of the eight Divisions, the Chairmen of the five Sections of the Administrative Division, and ——— members at large.

1. Administrative Division: Sections on Foreign Relations; Governmental Relations; Relations with State Research Committees; Industrial Relations; Educational Relations.
2. Military Division.
3. Engineering Division.
4. Division of Physics, Mathematics, Astronomy, and Geophysics.
5. Division of Chemistry and Chemical Technology.
6. Division of Geology, Mineralogy, and Geography.
7. Division of Medicine, Hygiene, Surgery, Anatomy, Anthropology, Physiology, Psychology, and Zoology.
8. Division of Agriculture, Forestry, Botany, and Fisheries.

In adopting this plan, it was recognized that part of the work in Zoology would fall within Division 8.

It was also voted that an Executive Committee of the Executive Board be appointed to consist of the General Officers of the Council and of the Chairmen of the Sections of the Administrative Division to serve between meetings of the Executive Board for the consideration of current business.

Upon motion, the present officers of the Council were nominated and elected as General Officers of the War Organization of the Council as follows:

Chairman, George E. Hale.

First Vice-Chairman, Charles D. Walcott.

Second Vice-Chairman, Gano Dunn.

Third Vice-Chairman, Robert A. Millikan.

Upon motion of Mr. Hale the following additional officers were elected:

Executive Secretary, John Johnston.

Treasurer, Witman Cross.

Assistant Secretary, Walter M. Gilbert.

The treasurer was authorized to sign checks drawn on the bank accounts of the Council in the Riggs National Bank and with the National Academy of Sciences.

Upon further motion the following chairmen for sections of the Administrative Division were nominated and elected:

Section on Foreign Relations, S. W. Stratton.

Section on Relations with State Research Committee, J. C. Merriam.

Section on Industrial Relations, John Johnston.

Upon motion of Mr. Bogert, the Executive Committee of the Administrative Division was requested to serve as a nominating committee for positions of Chairmen and Vice-Chairmen of the other Divisions and Sections of the War Organization. Subsequently, Mr. Hale, as spokesman for the nominating committee, submitted recommendations resulting in the election of the following persons to be the positions named:

Military Division, C. D. Walcott, Chairman; S. W. Stratton, Vice-Chairman.

Division of Physics, Mathematics, Astronomy and Geophysics, R. A. Millikan, Chairman.

Division of Chemistry and Chemical Technology, M. T. Bogert, Chairman; W. H. Walker, Vice-Chairman.

Division of Geology, Mineralogy and Geography, J. C. Merriam, Chairman; Whitman Cross, Vice-Chairman.

Division of Medicine, Hygiene, Surgery, Anatomy, Anthropology, Physiology, Psychology and Zoology, Simon Flexner, Chairman.

The Executive Committee of the Administrative Division was also given authority to make such further appointments as may be necessary to positions of Chairmen and Vice-Chairmen of Divisions and Sections of the War Organization, and to determine the number of members at large to be appointed on the Executive Board.

Mr. Hale explained that preliminary work of organizations had already been done in connection with the Divisions of Chemistry and Chemical Technology, of Geology, and of Medicine. Upon his recommendation, an Executive Committee of the Division of Chemistry and Chemical Technology was appointed to consist of the following persons: Marston T. Bogert, John Johnston, Arthur A. Noyes and William H. Walker.

He also explained that it is the purpose of the Division of Medicine to correlate all of the medical research work bearing on the war, and that to this end cooperative plans had been entered into through the Surgeon-General's office of the Army and other military and civil research agencies.

Upon invitation, Mr. Merriam outlined the proposed work of the Division of Geology, Mineralogy and Geography.

Mr. Hale emphasized the importance of undertaking at present the promotion of industrial research in preparation for post bellum conditions and activities. Upon his recommendation authorization was given for the appointment of an Advisory Committee for the Section on Industrial Relations of the Administrative Division of the Council, to consist of prominent leaders of industry in the United States.

Inasmuch as the former membership of the National Research Council is still maintained, it was decided, upon nomination of the Chairman of the Council to request the President of the National Academy of Sciences to appoint the following gentlemen, who will have an active part in the work, as additional members of the Council: Henry A. Bumstead, Director, Sloane Physical Laboratory, Yale University; Whitman Cross, Geologist, U. S. Geological Survey; Charles B. Davenport, Director, Department of Experimental Evolution, Carnegie Institution of Washington; Frank W. DeWolf, State Geologist of Illinois; Douglas W. Johnson, Professor of Physiography, Columbia University; John Johnston, Research Department, American Zinc Lead, and Smelting Company; Philip S. Smith, Administrative Geologist, U. S. Geological Survey; Colonel Ralph H. VanDeeman, Chief of Military Intelligence Section, Army War College; Lt. Col. William H. Walker, Assistant Director of the Chemical Service of the National Army.

Mr. Stratton explained the proposed activities of the Research Information Committee recently organized, and emphasized the need for the collection of information by the Research Council with regard to scientific activities and progress in the United States and abroad bearing upon the war.

Upon invitation of Mr. Hale, extended discussion took place relative to the future work of the National Research Council in cooperation with the National Academy of Sciences.

CARY T. HUTCHINSON, *Secretary.*